

Application of response surface methodology (RSM) to model the risk factor of early childhood caries (ECC) based on contour plot in east coast of peninsular Malaysia



Mohamad ArifAwang Nawi¹, Wan Muhamad Amir W Ahmad², Nor FaridMohd Noor³, Muhamad Nasir Rahmatdin⁴, Nik Muhamad Afiz Harom⁵, Nor Azlida Aleng⁶

School of Dental Sciences, UniversitiSains Malaysia, Health Campus
16150 KubangKerian, Kelantan, Malaysia^{1,2,3}

Department of Nautical Science and Maritime Transport, Faculty of Maritime Studies and Marine Science,
Universiti Malaysia Terengganu, 21300 Kuala Terengganu, Terengganu^{4,5}.

Department of Mathematical Sciences, Universiti Malaysia Terengganu, 21300 Kuala Terengganu,
Terengganu⁶.

Abstract—Early childhood caries or ECC is the most dominant disease in childhood that affecting many children in each country of the world. This study aimed at the application of response surface methodology (RSM) to model the risk factor contributes to early childhood caries based on the contour plot. Contour plot is a helpful visualization of the surface when the factors are no more than three. When there are more than three design variables, it is almost impossible to visualize the surface. The result shows only three variables have the relationship between the number of caries such as the status of caries (5.0973, $p = 0.000$), the income of the family (0.0009, $p = 0.003$) and types of water (-0.7927, $p = 0.049$). On the other hand, severe ECC experience is an important predictor of caries among children. High-income families can buy more sweets and snacks than others which is a contributory factor in creating dental caries among children. Through this study, the significant result is very important especially toward early children and especially their parents to prevent this problem. On the other hand, the government and health professional organizations should monitor the groundwater quality regularly which is used directly without treatment as drinking water.

Keywords—Early childhood caries, Response surface methodology, Contour plot

1. Introduction

Early childhood caries (ECC) are defined as the presence of one or more decayed, missing or filled tooth surfaces in any primary tooth in a child at the age of six and below [1]. ECC is the most dominant disease in childhood that affecting many children in each country of the world. The American Dental Association stated that ECC was a significant public health problem in deprived communities and throughout the general child population [2]. When compared with other common childhood diseases, ECC is five times as frequent as asthma and seven times as common as hay fever [3]. Therefore, the American Dental Association urges the public and health professionals to recognize that children's teeth are exposed to decay as soon as they begin to erupt, and ECC is a contagious disease.

This study aimed to focus attention on the environmental risk factors, such as the types of water they used, education level of the mother, age of children, status caries of children, number of family and nutrition status. The characteristics of primary teeth, eating habits, and plaque removal efficiency makes young children one a susceptible group [4]. The use of fluoride, access to dental care service, demographic background, and socio-economic status are the environmental risk factors related to ECC. In this context, disadvantaged children have a higher prevalence and higher ECC severity. In some developing countries, the prevalence of ECC is considered to be at epidemic proportions [5].

This study aimed to apply response surface methodology (RSM) to model the risk factor contributes to early childhood caries based on the contour plot. The response surface method is a set of techniques used in the empirical study of relationships. RSM is a collection of mathematical and statistical techniques for empirical model building, in which several variables influence response of interest and the objective is to optimize this response [6]. RSM is useful in three different techniques or methods such as statistical experimental design, in particular two-level factorial or fractional factorial design, regression modelling techniques and optimization methods. Usually, the most common applications of RSM are in Industrial, Biological and Clinical Science, Social Science, Food Science, and Physical and Engineering Sciences field [6].

2. Methodology

The RSM is a statistical tool or technique for designing experiments, building models, evaluating the effects of several factors and searching for optimum factors for desirable responses. From this technique, the interactions of possible influencing parameters on treatment efficiency can be evaluated and optimized with a limited number of planned experiments [6]. The first goal for the response surface method is to find the optimum response when there is more than one response then it is important to find the compromise optimum that does not optimize only one response. The second goal is to understand how the response changes in a given direction by adjusting the design variables. In the probabilistic analysis, an explicit or implicit functional relationship between input parameters and output response is required, which is normally difficult to establish except for simple cases and even the established functional relationship is sometimes too complicated to perform the conventional probabilistic analysis through integration or first or second-order derivatives [7].

From this Figure 1 below, each value of LDL and HDL generates a total of cholesterol. This three-dimensional graph shows the response surface from the side and it is called a contour plot. Sometimes, it is less complicated to view the response surface in two-dimensional graphs. The contour plots can show contour lines of LDL and HDL pairs that have the same response value of total cholesterol. An example of a contour plot is as shown in Figure 1 [8].

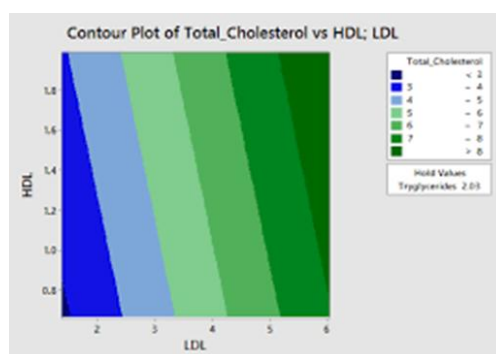


Fig 1: Contour plot (Wan Muhamad Amir, 2017)

To understand the surface of a response, graphs are helpful tools. But, when there are more than two independent variables, graphs are difficult or almost impossible to use to illustrate the response surface, since it is beyond 3-dimension. For this reason, response surface models are essential for analyzing the unknown function f [9]. When treatments are from a continuous range of values, then a Response Surface Methodology is useful for developing, improving, and optimizing the response variable. For example, the plant growth y is the response variable, and it is a function of water and sunshine. It can be expressed as:

$$y = f(x_1, x_2) + \ell$$

The variables x_1 and x_2 are independent variables where the response y depends on them. The dependent variable y is a function of x_1 , x_2 , and the experimental error term, denoted as e . If the response can be defined by a linear function of independent variables, then the approximating function is a first-order model. A first-order model with two independent variables can be expressed as

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \varepsilon$$

A first-order model uses low-order polynomial terms to describe some part of the response surface. This model is appropriate for describing a flat surface with or without tilted surfaces. Usually, a first-order model fits the data by least squares. Once the estimated equation is obtained, an experimenter can examine the normal plot, the main effects, the contour plot, and ANOVA statistics (F-test, t-test, R^2 , the adjusted R^2 , and lack of fit) to determine the adequacy of the fitted model [9].

The contour plot is a helpful visualization of the surface when the factors are no more than three. When there are more than three design variables, it is almost impossible to visualize the surface. For that reason, to locate the optimum value, one can find the stationary point. Once the stationary point is located, either an experimenter can conclude the result or continue in further study of the surface. The factorial designs are widely used in experiments when the curvature in the response surface is concerned. All treatment factors have 3- levels in the three-level factorial design. This design requires many runs, as a result, the confounding in blocks can be used. Also, the fractional factorial design can be an alternative approach when the number of factors gets large [9]. In RSM, the p-value of lack-of-fit, if >0.05 (not significant) means that the model fits well. And there is a significant effect on parameters on output response.

3. Result

The variable selection was done based on the recommendations proposed by Minitab 16 Statistical Software to ensure that this model fits the data. To determine the suitability of the studied model, several measures of goodness of fit were evaluated as such the p-value of lack-of-fit. Table 1 below are the three variables that the recommendations by Minitab through the linear model.

Table 1: Description of Data among Early Childhood Caries

Variable	Description
Caries	Number of caries among children
Nutrition status	Nutrition among children 1 = Severe thinness 2 = Thinness 3 = Normal 4 = Overweight 5 = Obesity
No. of Family	Number of sibling
Status of caries	Status of caries: 1 = Low 2 = Moderate 3 = Severe
Age	Age of children
Income	Parent income per month
Types of Water	Types of water they use 1 = Well water 2 = Water supply
Education M	Level of mother education 1 = Lower level 2 = Upper level

3.1 Multiple Linear Regression

The analysis of variance table summarizes the linear terms, quadratic terms and cross-product terms (See Table 2). The small p ($p = 0.000$) values for the linear terms suggest there is a linear association in the response surface.

Table 2: Analysis of Variance

Source	DF	SS	MS	F	P
Regression	7	3438.00	491.14	49.57	0.000
Residual Error	289	2863.51	9.91		
Total	296	6301.52			

Table 3 shows the results obtained by regression analysis of nutrition status, the number of families, the status of caries, age, income, types of water and education level of the mother with numbers of caries. There are only three variable have relationship between number of caries such as status of caries (5.0973 , $p = 0.000$), income of family (0.0009 , $p = 0.003$) and types of water (-0.7927 , $p = 0.049$). Based on Table 3, R square show that 54.6% in number of caries can be explained by status caries ($\beta = 5.0973$, $p < 0.05$), income of family per month ($\beta = 0.0009$, $p < 0.05$) and types of water they used ($\beta = -0.7927$, $p < 0.05$). Among the studied, factor status of caries was found to has the highest positive effect on the number of caries. It is important to check the adequacy of the fitted model because an incorrect or under-specified model can result in misleading conclusions. By checking the fit of the linear model, we obtained the lack of fit test value ($p = 0.880 > 0.05$). The result suggests that this model adequately fits the response surface very well. To see their association, contour plot analysis between three variables was plot separately and further discussion will discuss in detail.

Table 3: Regression Modelling of Early Childhood Caries (ECC)

Variable	Coefficient	Standard Error	Statistic T	P Value
Constant	-1.721	2.830	-0.61	0.544
Nutrition Status	0.2426	0.2564	0.95	0.345
No. of Family	-0.00900	0.09356	-0.10	0.923
Status of Caries	5.0973	0.2820	18.07	0.000*
Age	-0.3510	0.3826	-0.92	0.360
Income	0.0009131	0.0003008	3.04	0.003*
Types of Water	-0.7927	0.4002	-1.98	0.049*
Education Mother	-0.2318	0.3382	-0.69	0.494
R Square	5.46			
R Square (Adj)	5.35			
Lack of fit				0.880

3.2 Contour Plot

Figure 2 shows the contour plot for the number of caries (Y) vs. income ($X1$) and the status of caries ($X2$). The counter plots show the highest value for the number of caries among preschool children is obtained when the status of caries is high and the income of the parent is also high. This area appears at the upper right corner of the plot.

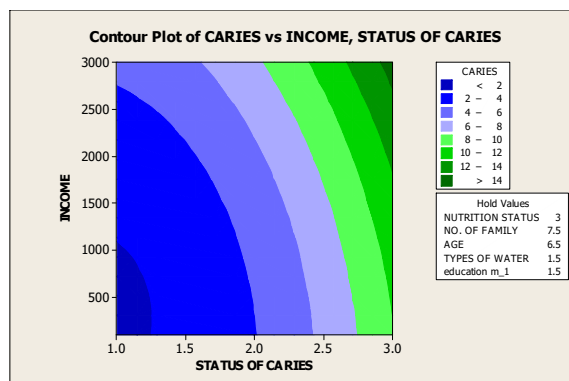


Fig 2: Contour Plot of Caries vs. Income and Status of Caries

Figure 3 shows the contour plot for the number of caries (Y) vs. types of water ($X1$) and the status of caries ($X2$). The counter plots show the highest value for the number of caries among preschool children is obtained when the status of caries is high and types of water are low (using well water). This area appears at the lower right corner of the plot.

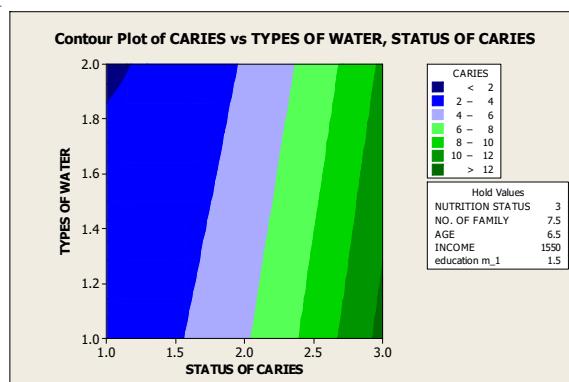


Fig 3: Contour Plot of Caries vs. Types of Water and Status of Caries

Figure 4 shows the contour plot for the number of caries (Y) vs. types of water (X_1) and the income of the parent (X_2). The counter plots show the highest value for the number of caries among preschool children is obtained when the income of the parent is high and types of water are low (using well water). This area appears at the lower right corner of the plot.

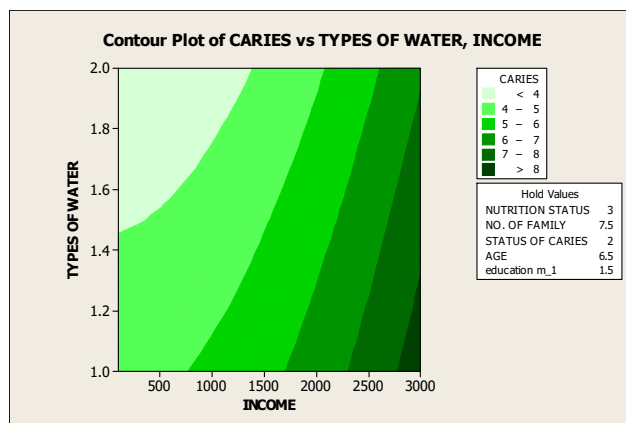


Fig 4: Contour Plot of Caries vs. Types of Water and Income

4. Discussion and Conclusion

Based on the result presentation above, only the status of caries, family income, and types of water are significant to early childhood caries among children age 6 and 7. The study from Petersen, Estupinan, Ndiaye, [10] state that children's quality of life can be severely affected by severe caries because of their pain and discomfort which could lead to disfigurement, acute and chronic infections, and altered eating and sleeping habits. As a result, the risk of hospitalization, high treatment costs, and loss of school days with the consequent diminished ability to learn. On the other hand, severe ECC experience is an important predictor of caries among children. To prevent and control ECC, such as creating strategies, it is essential to improving general and oral health in the future [10].

Other study findings indicate that children from low socioeconomic families have higher risks of developing dental caries [17]. Different studies also have confirmed that children with low incomes of the family have more dental caries [13]. From this study, there was a significant relationship between higher incomes of the family with early childhood caries. In other words, among eight articles that had assessed the relation between income and early childhood caries, only three articles have reported that there is a significant relationship between higher income of the family and dental caries [11]. Firstly, this finding is logical for these articles because high-income families can buy more sweets and snacks than others which is a contributory factor in creating dental caries among children [14]. The second statement is different income levels may not have a significant effect on dental health behaviours; moreover, some families may not express their real monthly income [15].

Besides that, children who are using well water or groundwater is the most risk factor for early childhood caries. Most of the families affected by high fluoride concentration in well water live in tropical countries where the per capita consumption of water is more because of the prevailing climate. In most cases, fluoride in well water or groundwater is contributed by the host rocks which are naturally rich in fluoride. Because of rock water interaction, long residence time and evapotranspiration, the concentration of fluoride increases. Most of the studies indicate the increase in fluoride composition in groundwater with an increase in depth from the ground surface. Paradoxically, low levels of fluoride intake help to prevent dental caries. The control of drinking-water quality is, therefore, critical in preventing fluorosis. Excessive intake of fluoride

causes the condition and its effect on people fluorosis. The dental effects of fluorosis develop much earlier than the skeletal effects in people exposed to large amounts of fluoride. Clinical dental fluorosis is characterized by staining and pitting of the teeth. In more severe cases, all the enamel may be damaged [16]. The government and health professional organizations should monitor the groundwater quality regularly, which is used directly without treatment as drinking water.

Therefore, parents and caregivers play an important role in promoting oral health for their children. Evidence suggests that parental engagement is required during the perinatal period for the effective prevention of ECC. The government and health professional organizations should reduce disparities in ECC between different socioeconomic groups within countries, as well as reduce inequalities in ECC across countries. Besides, the government should take responsibility for training health-care providers to perform epidemiological surveillance of ECC among young children periodically. In addition to community health workers, social workers and dieticians can play an effective role in the prevention of ECC [17].

5. Acknowledgments

The authors would like to express their gratitude to Universiti Sains Malaysia (USM) for providing the research funding (Short Term Grant No.304/PPSG/6315410, School of Dental Sciences, Health Campus, Kelantan, Malaysia).

6. References

- [1] American Academy of Pediatric Dentistry. Policy on early childhood caries (ECC): classifications, consequences, and preventive strategies. *Pediatr Dent*. 2016;38:52-54.
- [2] American Dental Association. Statement on early childhood caries. <http://www.ada.org/en/about-the-ada/ada-positions-policies-and-statements/statement-on-early-childhood-caries>. [Accessed February 10, 2018].
- [3] Bagramian RA, Garcia-Godoy F, Volpe AR. The global increase in dental caries: a pending public health crisis. *Am J Dent*. 2009;22:3-8.
- [4] Alazmah A. Early childhood caries: a review. *J Contemp Dent Pract*. 2017;18:732-737.
- [5] Mantonanaki M, Koletsi-Kounari H, Mamai-Homata E, Paaioannou W. Prevalence of dental caries in 5-year-old Greek children and the use of dental services: evaluation of socioeconomic, behavioural factors and living conditions. *Int Dent J*. 2013;63:72-79
- [6] Montgomery Douglas C (2005). *Design and Analysis of Experiments Response Surface Method and Designs* (New Jersey, John Wiley and Sons, Inc).
- [7] Oehlert GW (2000). *Design and Analysis of Experiments: Response Surface Design* (New York: W.H. Freeman and Company).
- [8] Wan Muhamad Amir W Ahmad, Nor Farid Mohd Noor, Zainab Binti Mat Yudin, Nor Azlida Aleng, Ruhaya Hassan. 2017. Fasting Blood Sugar Control and Total Cholesterol Algorithm for Diabetes Mellitus and Hyperlipidaemia Disease Patients: An SAS Methodological Performance. *International Journal of Public Health and Clinical Sciences e-ISSN: 2289-7577*. Vol. 4:No. 6.

- [9] Nuran B (2007). The response surface methodology. ccepted by the Graduate Faculty, Indiana University South Bend, in partial fulfillment of the requirements for the degree of Master of Science. Master's Thesis Committee.
- [10] Petersen PE, Estupinan-Day S, Ndiaye C. WHO's action for continuous improvement in oral health. *Bull World Health Organ.* 2005;83:642.
- [11] MohammadrezaAmiresmaili, Saeed Amini, ArashShahravan, Reza Goudarzi, Seyed Hossein SaberiAnari, ZohreAnbari, and MahtabGhanbarnejad. 2018. Relation between
- [12] Socioeconomic Indicators and Children Dental Caries in Iran: A Systematic Review and Meta-analysis. *Int J Prev Med*; 9: 71.
- [13] Kumar S, Tadakamadla J, Kroon J, Johnson NW. Impact of parent-related factors on dental caries in the permanent dentition of 6-12-year-old children: A systematic review. *J Dent.* 2016;46:1–1.
- [14] Pakpour AH, Hidarnia A, Hajizadeh E, Kumar S, Harrison AP. The status of dental caries and related factors in a sample of Iranian adolescents. *Med Oral Patol Oral Cir Bucal.* 2011;16:e822–7.
- [15] RigiLadez M, Ghanbariha M, Badiee M, Abdolazimi Z. The relationship between dental caries and some socio-economic factors in 35-44 years old adults in some urban areas ofSistan&Baluchestan. *J ShahidSadoughiUniv Med Sci.* 2012;20:454–63.
- [16] World Health Organization (WHO). 1999. Guidelines for drinking-water quality. Vol. 2. Geneva, 1999 (Second edition).
- [17] Edelstein BL. Pediatric dental- focused interprofessional interventions. *Dental Clinics.* 2017;61:589-606.



This work is licensed under a Creative Commons Attribution Non-Commercial 4.0 International License.